MEMOIRS

OF THE

CARNEGIE MUSEUM

Vol. IX. No. 3.

THE SKULL OF DIPLODOCUS[1]

By W. J. Holland, *Director Emeritus of the Carnegie Museum.*

(Plates XL–XLIII.)

Introductory.

When I received an invitation to contribute a short article to the Williston Memorial Volume, there was immediately recalled to my mind a day in the summer of the year 1899, when with Dr. S. W. Williston as my guest I sat and chatted with him through the early morning hours on the shady side of a shack in the bad-lands of Wyoming. I had gone thither to oversee the work which was being done by my assistants in recovering the remains of a specimen of *Diplodocus*, which is now one of the many ornaments of the Gallery of Paleontology in the Carnegie Museum. Replicas of this skeleton are to be found in many of the museums of foreign lands. As Williston and I sat and talked, he grew reminiscent. He told me that he had been the original discoverer of the material upon which Professor Othniel C. Marsh had founded his description of the genus *Diplodocus*.

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[1] Shortly after the death on August 30, 1918, of Professor Samuel Wendell Williston, a movement to bring out a memorial volume in his honor was initiated. A committee composed of some of the most eminent paleontologists in both hemispheres was formed. Dr. W. K. Gregory of the American Museum of Natural History in New York became the Secretary. Important papers were submitted by a number of the leading paleontologists of Europe and America. When the papers had been collected and everything was ready for publication, the National Academy of Sciences in Washington, who had been requested to take the matter under their auspices, declined for unexplained reasons to act. The various manuscripts which had been collected were returned by Dr. Gregory to their authors with the request that when publishing the same a note should be made that the paper had been originally intended to form a chapter in the Williston Memorial Volume. This note is written in compliance with this request. *W. J. Holland.*

As I recall the story, Williston detected the earliest known remains of the animal at the well known locality, near Felch's Ranch, not far from Canyon City, Colorado, in the year 1877. The spot is one, where Williston subsequently worked, and where for a couple of years parties from the Carnegie Museum at a later date carried on extensive excavations. Williston told me that at the time of his first visit to the spot he lived in fear of hostile Indians, who were not far away, and that he worked rapidly and hurriedly, taking up what came to hand and hastily boxing and shipping the material as it was recovered from the matrix. He told me that, had it not been for his fear of being made the target of bullets at any moment, he might have secured much more of the skeleton than he did on the occasion of his first visit to the place. The parts which he obtained, now in the Peabody Museum of Yale University, were one of the posterior limbs and portions of the tail. The structure of the chevrons of the tail led Professor Marsh to coin the generic name, which he gave to the reptile.[2] Subsequently on the occasion of later visits to the same spot Williston and the late M. P. Felch found much other material, probably pertaining to the same individual, as well as to other individuals of the same genus. But all of this material was more or less fragmentary.

This early discovery by my friend, Dr. Williston, of the type of the genus *Diplodocus* seems to me to make it appropriate that I should take as my theme something bearing upon the anatomy of the genus, which he was the first to unearth.

Since 1877 our knowledge of the reptiles belonging to the genus *Diplodocus* has been greatly enlarged. Passing over the important discoveries which were made by parties working under Dr. Henry Fairfield Osborn at Como Bluff, Wyoming in 1897[3], and the still more extensive discoveries made by the Carnegie Museum near Sheep Creek, Laramie County, Wyoming, in the years 1899 and 1900, upon which more or less full accounts have already been published,[4] it is worthy of note that among the collections obtained at the quarry discovered and opened under my direction near Jensen, Uinta County, Utah, are several specimens of the skull belonging to this genus, three of which have been freed from the matrix and which possess much interest. A brief account of these skulls, with appropriate illustrations, appears in the following pages.

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[2] *Diplodocus* from διπλόος = *double;* and δοκός, ἡ = *beam,* or *rafter.* Compare Matthew, VII, 5: Ὑποκριτά, ἔκβαλε πρῶτον τὴν δοκόν ἐκ τοῦ ὀφθαλμοῦ σου—"Thou hypocrite, cast out first from thine own eye the *beam.*"

[3] Osborn, H. F., Memoirs A.M. N. H., Vol. I, No. 5, pp. 191–214, plates XXIV–XXVIII.

[4] Hatcher, Memoirs C. M., Vol. I, No. 1, pp. 1-63, plates I–XIII.
Holland, W. J., *l. c.*, Vol. II, No. 6, pp. 225–278, plates XXIII–XXX, etc., etc.

Earlier Accounts of the Skull of Diplodocus. The first description of the skull of this genus was given by Professor Marsh in Part VII of the series of papers published by him under the title: "Principal Characters of American Jurassic Dinosaurs." It appeared under the subtitle "On the Diplodocidæ, a New Family of the Sauropoda" and may be found in the *American Journal of Science,* Ser. III, Vol. XXVII, pp. 160–168, 1884, accompanied by Plates III and IV. This account was subsequently reproduced (1896) in the *Sixteenth Annual Report of the U. S. Geological Survey,* Part I, pp. 175–179, Plates XXV–XXVI.

The material upon which Professor Marsh founded his description and figures of the skull is still preserved in the United States National Museum (U. S. N. M., Nos. 2672 and 2673). It was collected by Williston and Felch, near Canyon City. The writer of these lines is very familiarly acquainted with these specimens, as they were with the greatest courtesy loaned to the Carnegie Museum at the time when the latter institution was engaged in preparing a replica of *Diplodocus* to be presented to his Majesty, King Edward VII. At that time, although we possessed an almost complete skeleton of a single individual, we did not have a skull in its entirety. The only remains representing the cranium of the animal in our collection consisted of what was at that time believed to be the posterior part of the skull of a rather small individual, recovered by W. H. Utterback in Wyoming, in the year 1902 (C. M. Acc. No. 662 (22)). Employing the anterior portion of the skull belonging to the United States National Museum (No. 2673) which is entirely freed from the matrix and the occipital portion of the skull in our own possession we effected a restoration of the skull, conformed to Professor Marsh's original description. In the light of recent discoveries we have reason to congratulate ourselves upon the general accuracy of this restoration. A full account of these matters may be found in the *Memoirs of the Carnegie Museum,* Vol. II, pp. 227–246, where the material we used is fully described and figured.

There is also given in the paper just cited a posterior and lateral view of a skull of *Diplodocus* preserved in the American Museum of Natural History in New York (A. M. N. H., No. 969). This is a restoration made by Mr. Adam Hermann, at that time the Chief Preparator in the Paleontological Laboratory of that Museum, working under the supervision of Dr. Henry Fairfield Osborn. The externally visible portions of this skull are to a considerable extent modelled in plaster according to the figures given by Professor Marsh.

For a number of years the only material upon which an exact knowledge of the structure of the cranium and lower jaws of the genus *Diplodocus* was based was the material referred to in the preceding account. I may say in passing that the occipital portions of the cranium employed by me in my restoration in the light of recent studies is found to be doubtfully referable to *Diplodocus longus* Marsh. It is not, however, necessary to here go into details upon this point. I will refer to the matter again in this paper. Professor J. B. Hatcher and I were fully in accord at the time in attributing this fragment to the genus *Diplodocus,* with which it was found to agree after a comparative study of the papers and figures of Marsh. There are, however, certain small, but very decided differences, which point to at least specific non-identity. All of the material we had at our command was more or less defective, but there was enough to decipher with much certainty the principal characteristics of the skull. In fact it is rather astonishing to see how Professor Marsh with the somewhat crushed and broken material preserved in the United States National Museum was able to almost exactly restore the features of the skull, now that practically perfect and almost uncrushed specimens are available for comparison.

THE NATIONAL DINOSAUR MONUMENT.

In the fall of the year 1908 the writer visited his associate, Mr. Earl Douglass, who had been sent by him to explore the Eocene deposits of the Uinta Basin. At the time of my visit Mr. Douglass was located at a place known as "Well No. 2" near Bonanza on the stage-road leading from Dragon to Vernal, Utah. Far away on the northwestern horizon could be seen the snow-capped ranges of the Uinta Mountains. A study of the maps of Hayden's Survey showed certain areas to be designated as "Jurassic," and therefore likely hunting-grounds for the remains of dinosaurs. In fact Mr. O. A. Peterson as early as 1892, while collecting for the American Museum of Natural History, in whose employment he was at that time, had found some fragmentary remains of dinosaurs in the vicinity of Jensen on the Green River. Mr. Douglass also before my arrival had made an excursion to the region of Blue Mountain near the point where the Green River cuts through the Uinta range, and had discovered some flotsam and jetsam of dinosaurian material in the ravines. Orders were given that the team and wagon, a supply of water, and provisions should be made ready, and one bright morning, just as the sun was rising over the desert and arid plains, the writer accompanied by Mr. Douglass, who acted in the capacity of teamster, friend, and philosopher, began a tour of investigation. We took our way over "Dead Man's Bench" toward the distant mountains. The interesting events of that long and somewhat trying journey, for the most part under a burning sun, may be passed over. A week was spent in exploring. It suffices to say that enough was seen to convince the writer that a diligent and painstaking search for dinosaurian remains would be richly rewarded. Accordingly in the following year (1909) Mr. Douglass was instructed, when returning to Utah, to remove his camp from the Uinta Basin to the foothills near the Green River on its right bank above the little Mormon hamlet, known as Jensen, and begin a systematic investigation of the exposures of the Morrison or Atlantosaurus Beds, which we had detected at that place. He was at first greatly discouraged, but was finally rewarded by the discovery in September, 1909, at an elevation of about a mile above sea-level, of the bed of an old river, tilted up at an angle of about 60° with the horizon. In the sandbars of this ancient stream, now turned into sandstone, were the petrified remains of numerous dinosaurs, many of them, as the result proved, consisting of skeletons not greatly dislocated, The first skeleton recovered was that of the huge beast. which, eclipsing the *Diplodocus* in size, the writer has had the pleasure of naming *Apatosaurus louisæ* in honor of Mrs. Andrew Carnegie,[5] a step which Mr. Carnegie laughingly approved, because he said: "She is the most important member of the firm." This great skeleton, as it stands alongside that of *Diplodocus carnegiei*, excites the wonder of multitudes.[6]

At the time Mr. Douglass and I began our work the land had not been thrown open to settlement. We were carrying on our explorations under a permit given to us by the authority of my good friend, Mr. James Rudolph Garfield, the then Secretary of the Interior. Some years afterward the land was thrown open to settlement. To avoid being made to pay tribute to some adventurer, who might see fit to file a claim to the barren acres upon which we were carrying on our work, I instructed Mr. Douglass to file a claim under the existing laws. He accordingly filed a claim under the provisions of the law granting citizens of the United States the right, under certain conditions, to take up land for mining and quarrying purposes. Some very learned subordinate in the Department of the Interior, passing the claim under review, decided that "fossil bones," mentioned by Mr. Douglass in his application, are not "mineral," and our request to be granted title to the land was disallowed. I have always been puzzled to know, since this formal decision was rendered, where in the realm of material things to put silicified bones. If they do not come within the category of mineral substances, what are they? On one occasion I called the attention of the late Franklin K. Lane, Secretary of the Interior, who was paying a visit to the Carnegie Museum, to this decision. He had no reply to make, but grew very red in the face, and "looked foolish," as the boys say. However, there are always by the orderings of a kind Providence ways in which to accomplish laudable purposes. I appealed to my friend, Dr. Charles D. Walcott, the Secretary of the Smithsonian Institution, to help me in my perplexity, and he pointed out that in the year 1906 the Congress of the United States had passed "An Act for the Preservation of American Antiquities," and he proposed under the provisions of this Act, which seemed to be somewhat elastic, that the little tract of barren ground, where we had been digging for fossil bones, should be set apart by presidential proclamation as a "national monument." To cut a long story short, this was done, and under date of October 4, 1915, the land was set apart by President Wilson as "The National Dinosaur Monument." Permission under the "Rules and Regulations" was given to the Director of the Carnegie Museum to continue the work, which had already been carried on by him and his associates for the preceding six years, and we were freed from the constant fear, which had haunted us, of being compelled to submit to the exactions of some wandering sheep-herder or so-called "Homesteader," either of whom might have taken up the land under existing constructions of the law, without our being able to prevent it, and then turned about and demanded rental for the treeless ground.

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[5] Annals Carnegie Museum, Vol. X, 1916, pp. 143–145.

[6] A monographic account of the osteology of *Apatosaurus* is being prepared by the writer, all the illustrations having been drawn, and it is hoped that it may shortly be published.

The quarry near Jensen has yielded a good deal of material, some of it excellent, some of it fairly good, some of it of but little value. The matrix is sandstone of varying degrees of hardness. The bone-bearing strata are only reached by a great deal of "uncovering," which is expensive and tedious. The advantage of the location is the fact that the remains found here are in many cases discovered to be lying in very nearly the positions in which they were originally deposited millions of years ago. It is possible in many cases to determine the relationship of the bones of the skeletons as they are found. They have not been as much scattered and jumbled together, as is the case in many localities where dinosaurian remains are abundant. This fact has in the main persuaded us to persist, as long as we have, in carrying on our work at this point. However, there is not always continuity of location in the bones of specimens. One of the skulls, of which I am about to speak in detail, illustrates the latter assertion. The most perfect skull was found entirely apart from any other skeletal material. It was imbedded in a layer of very soft sandstone disassociated from any other fragments. It is designated in the Departmental Catalog of the Carnegie Museum as No. 11,161. The second skull, No. 3,452, is closely articulated with the cervical vertebræ, the occipital condyle being in juxtaposition with the cup of the atlas, thus settling beyond the shadow of a doubt the fact that the skull attributed to the genus *Diplodocus* really belonged to it, which is not the case with some other genera of the sauropod dinosaurs, which have been reconstructed by students from widely scattered material, in fact so widely scattered, as to leave a great doubt in the minds of careful students whether mistakes have not been made in the association of the skulls with the other material. The third skull, representing a very small individual, bears the Departmental No. 11,255.

SKULL OF DIPLODOCUS LONGUS Marsh.

(Carnegie Museum, No. 11,161.)

This skull is undoubtedly the most perfect specimen of a skull pertaining to the genus *Diplodocus*, which up to the present time has been obtained.

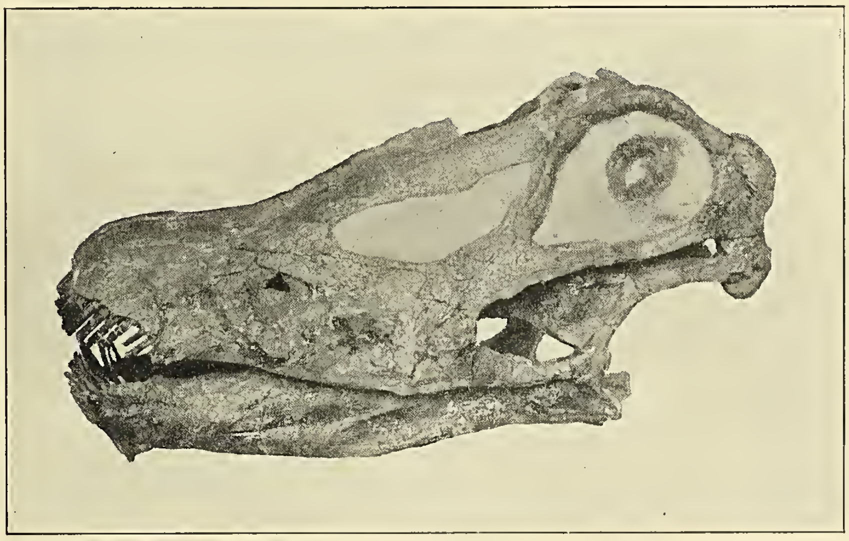

FIG. 1. Photograph of left side of skull of Diplodocus. (C. M. No. 11,161.)

It was found at the western extension of the quarry opened by the Carnegie Museum on the eminence, to which the writer has been in the habit of referring in his publications as "Dinosaur Peak." The skull was found apart, not closely associated with any other remains. It was imbedded in a layer of soft white sandstone.

Vertically the skull has apparently sustained no crushing whatever. Laterally it has sustained a little crushing, so that the right side is slightly compressed and not quite symmetrical, a fact which is shown in the figures given on the plates.

The skull is somewhat smaller in size than the skull employed by Professor Marsh in preparing his account of the type of the genus, the material for which was obtained from the Morrison beds near Canyon City, Colorado.

So far as the writer is aware, Professor Marsh in his writings gave no exact measurements of any of the material relating to the skull of his *Diplodocus longus*, and simply states that the figures published in the American Journal of Science, Vol. XXVII, 1884, Plate III, figs. 1–3, are "one-sixth natural size." This would give a length from the anterior margin of the premaxillaries to the occiput of about 570 mm. In the restoration of the skull made by the writer and Mr. A. S. Coggeshall, which has been used in the Carnegie Museum and in all the replicas of the skeleton of *Diplodocus*, the length is approximately 590 mm. The restored skull at the American Museum of Natural History, for a cast of which we are indebted to the Trustees of that institution, measures approximately 560 mm. from the occiput to the anterior margin of the premaxillaries. The length of the skull which we are here considering (Carnegie Museum No. 11,161) is 520 mm. from the anterior margin of the premaxillaries to the occiput. The skull (Carnegie Museum No. 3,452) is considerably smaller, measuring only 450 mm. in length, measured in the same way. The third skull which is reasonably perfect (Carnegie Museum No. 11,255) is the smallest in our possession.

We have in our possession a skull (Carnegie Museum No. 11,162) found associated with the skeleton of *Apatosaurus louisæ* Holland, which is thoroughly diplodocine in its features and particularly in its dentition. At moments I have been almost inclined to regard this skull as belonging to *Apatosaurus* (See Annals Carnegie Museum Vol. IX, pp. 273–277; Vol. X, p. 143). In its length it exceeds all the diplodocine skulls thus far discovered, being 640 mm. in length. The association with the other skeletal remains of *Apatosaurus* (*Brontosaurus*) of the skull, attributed by Marsh to that genus, has seemed to me to have been rather arbitrary, though it may be that he was right. Had he opened the quarry at The National Dinosaur Monument and found the skull of which I am speaking, removed only a few feet from the anterior end of the cervical vertebræ, I very much question whether he would not have assigned this skull to the remainder of the skeleton which was *in situ*.

We have in our possession fragments of other diplodocine skulls, of which I shall not here speak, as they have not as yet been freed from the matrix and prepared for careful examination.

The skull (No. 11,161) which forms the immediate subject of consideration is fully adult. This is revealed by the more or less perfect coössification of the different bones of which it is composed. So complete is this coössification that in a number of cases it is almost impossible to detect the lines of union between the different elements. The sutures are, however, in most cases decipherable, and agree in the main with other material which has been studied.

The Eye.—One of the remarkable features of this skull, which has not been found in any other specimen, is the preservation on the right side of considerable portions of the sclerotic wall of the eye. This is clearly shown in Fig. 1, and on Plate XL. A careful microscopic examination of what remains of the eye does not appear to reveal any sclerotic plates, such as are found in many of the reptilia and birds. The membrane appears to have been continuous and almost homogeneous in its structure, the tissue consisting of fibres arranged in circular (?) layers surrounding the pupil of the eye. I have entirely failed to detect after careful examination any sclero-skeletal plates.

Dentition.—Professor Marsh in his account of the material before him stated that the premaxillary bone was provided with four teeth and that the maxillaries were each provided with nine teeth. This was absolutely true of the specimens, (Nos. 2672 and 2673 U. S. N. M.) upon which he founded his description of the skull, and is also true, so far as the premaxillaries are concerned, of the specimen preserved in the American Museum of Natural History. However, in the case of the present specimen (Carnegie Museum No. 11,161) there is interpolated a large tooth which emerges at the commissure of the premaxillaries. There apparently was some malformation and dislocation of the teeth of the premaxillaries during the life-time of the animal. The number of teeth in the supra-maxillaries is evidently variable, as I have elsewhere pointed out (See Memoirs of the Carnegie Museum, Vol. II, p. 240). There are ten teeth in the right maxillary of the specimen preserved in the American Museum of Natural History and eleven in the left maxillary of that specimen. In the specimen before us there are ten teeth in the left maxillary and eleven in the right maxillary. From the foregoing statements it is clearly seen that the number of teeth in the upper jaws is not definitely fixed in number. They may range in the maxillaries from nine to eleven, and possibly even more.

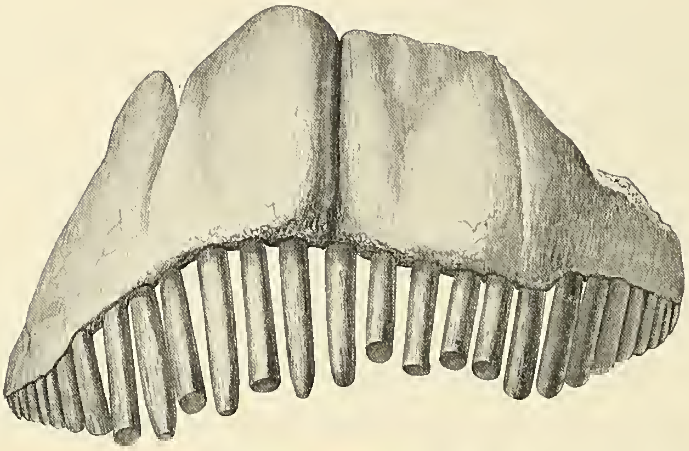

FIG. 2. Anterior view of the teeth of Diplodocus, (C. M. No. 11,161.) One-half nat. size.

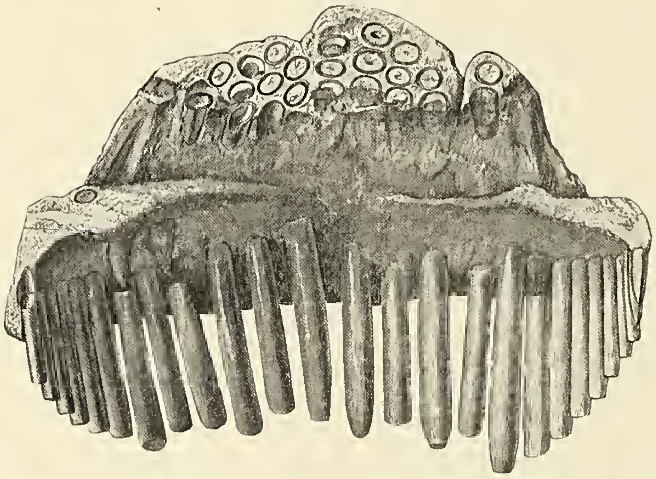

FIG. 3. Posterior view of teeth of Diplodocus, (C. M. No. 11,161), showing successional teeth above.

At the time that the skull (No. 11,161) was being removed from the matrix the anterior portion was accidentally broken away from the rest of the specimen. Before restoring the fragment to its place, I had two drawings of it carefully made by Mr. Sydney Prentice, our accomplished draughtsman, who, by the way, was a former pupil at the University of Kansas of Professor S. W. Williston. One of these drawings (Fig. 2) gives an excellent view of the anterior portion of the skull showing the dentition as it appears in a frontal view. The other drawing (Fig. 3), gives a view of the same fragment viewed from behind. The latter is interesting, inasmuch as it shows the successional teeth in the sockets in which they were formed, and from which they issued continuously in order to replace teeth which were worn out or lost. These curious reptiles throughout life were constantly teething. The anterior portions of the premaxillaries and maxillaries as well as of the dentary must have been more or less abundantly supplied with nutritive material for the development of teeth. A vegetative process was continuously going on at the anterior extremities of both upper and lower jaws. The teeth, though somewhat firmly fixed in the alveoli, were weak, easily lost, and quickly replaced.

An interesting phenomenon reveals itself in the teeth represented in figures 2 and 3. In these figures the teeth are shown to be worn off at almost right angles to their axes. This is especially visible in the case of the older teeth, while the newer teeth, which are longer than the older teeth, only begin at their extremities, to show signs of this wearing off, but on the same plane and at the same angle with their axes, as the older teeth. As the axes of the teeth in the upper and lower jaws are placed at an obtuse angle in relation to each other it seems to the writer quite impossible to think that this wear is due to attrition between the teeth in the upper and lower jaws. The teeth contained in the lower jaw are much smaller than those in the premaxillaries and supero-maxillaries, and in the skull which we are considering do not show evidence of having been brought into opposition with the teeth of the upper jaw. The teeth of the lower jaw are exceedingly small and weak, having half the diameter (in many cases less than half the diameter) of the teeth in the upper jaw, and the wear which is noticeable upon their crowns does not suggest that it could have been produced by friction against the teeth in the upper jaw. In fact the wear apparent upon the lower teeth is on a plane more or less opposite to that shown upon the upper teeth and not parallel with it. In the small skull (Carnegie Museum No. 11,255) the teeth are, so far as visible, sharply pointed and show no signs of transverse wear.

The teeth appear to the writer to have been organs of prehension rather than of mastication. They were "nippers" adapted to seizing the objects upon which the animal fed, or "scrapers," dental rakes, in which the upper set were mainly functional as shown by their size and wear.

The question naturally arises in what way the peculiar wear of these teeth was brought about. The view, originally propounded by Marsh, that these creatures were herbivorous, feeding upon soft succulent vegetation, has long been held. It is conceivable that such vegetation in the form of algæ and aquatic plants growing in water on the surfaces of rocks may have been the food of these creatures, and the wear of the teeth, of which I have been speaking, may have been produced by scraping upon the surfaces of the stones to which the plants were attached. In the *American Naturalist*, Vol. XLIV, 1910, p. 282, I suggested that these animals might have fed upon the starchy material contained in the trunks of cycads which were abundant in their time. It is possible that the very singular wear of the teeth might have been produced by constant attrition against the hard inner surfaces of the walls of the trunks of the cycads, which may have been ripped open by the great claws of the fore feet, as I suggested. However, Dr. G. Tornier (Bericht d. Senkenberg. Naturf. Ges., 42, 1911, p. 113) followed by Richard Sternfeld, in a German popular magazine, "Aus der Natur," has made the suggestion that these creatures fed upon animal food, Tornier says 'fishes;' Sternfeld says 'freshwater bivalves.' Tornier maintains that they were not herbivorous, but dug up their food from the beds of streams. *Quien sabe*? It is conceivable that these teeth might have been employed for the purpose of seizing shell-fish which the creatures scraped out of the beds of streams, along the margins of which their remains have hitherto always been found. In Fig. 4 I give an outline drawing of the manner in which the *Diplodocus* might have seized a bivalve in his jaws. Upon the supposition that the animal fed upon mussels, which he must have swallowed whole, the wear of the teeth might be explained by such a habit. *Naiades* are indeed more or less abundant in the sandstones and clays whence the remains of *Diplodocus* have been taken. It is, however singular that where skeletons have been found *in situ* no shells have been discovered massed together where the stomach of the reptile might be supposed to have been located. We have uncovered several skeletons of these creatures with the vertebræ and ribs in place and I have always instructed Mr. Douglass, who has had supervision of the work in the field, to search for gizzard-stones and any detritus which might throw light upon the contents of the viscera of the animals. So far, however, he has not reported to me any accumulation of the valves of

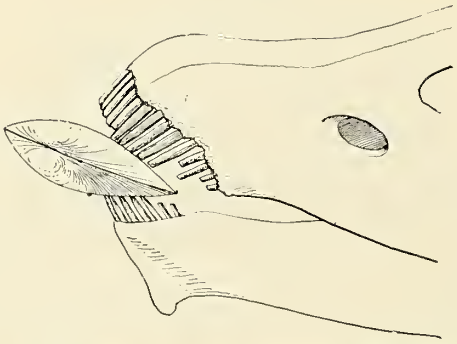

Fig. 4. Jaws of Diplodocus seizing a mussel.

pelecypods or other mollusks detected as lying between or near the ribs of any of the specimens which have been unearthed. There is thus so far no confirmation of Tornier's theory, nor, I may say for that matter, of Professor Marsh's statement that these creatures were herbivorous. I confess finding myself compelled to announce myself as an agnostic, so far as the mode in which these creatures obtained their food and the nature of their aliment is concerned. I am not in the least prepared on this point to dogmatize.

The order in which the teeth succeeded each other is a subject of inquiry, which in the light of the material before me leads to a query as to the correctness of the figure given by Professor Marsh in the American Journal of Science, Vol. XXVII. On Plate 4, Fig. 3, he gives a diagrammatic drawing of the teeth of the maxillary of *Diplodocus longus*, which has often been reproduced in textbooks. The large skull in our possession found associated with the remains of *Apatosaurus* (Carnegie Museum No. 11,162) shows an abrasion on the anterior portion of the right maxillary revealing the successional teeth in such a way as to suggest that the manner of succession was different from that indicated by Professor Marsh in his figure to which reference has just been made. In the figure given by Marsh the distal end of tooth No. 2 is shown *underlapping* the proximal end of tooth No. 1. In our specimen (Carnegie Museum No. 11,162) the successional teeth are shown with their distal ends *overlapping* the proximal ends of the anterior teeth. A careful and critical examination of the teeth in our specimen, No. 11,161, likewise reveals the fact that the successional teeth as they advanced *overlapped* and *did not underlap* the teeth which are on the point of being lost in this specimen. Several of the teeth, which are almost worn out, show the points

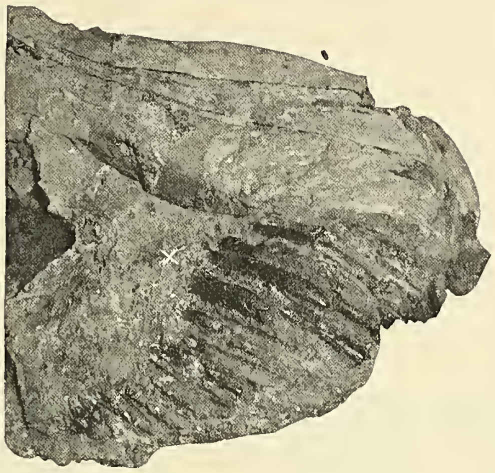

Fig. 5. View of anterior end of right upper jaw of diplodocine skull (C. M. No. 11,162) at X showing successional teeth overlapping teeth in front.

of their successors overlapping their proximal portions which have been already partly absorbed. (See Fig. 3). It is also quite plain in some cases that the successional tooth immediately followed the one preceding it, without any tendency to overlap. As the tooth in front was worn away and became obsolescent, the tooth following it pressed upon its proximal extremity and as this was gradually absorbed the successional tooth invaded its degenerating substance, (a familiar phenomenon in the case of mammalian teeth). This is shown on Fig. 6, at *a*, where the proximal end of a tooth about to be shed is shown with the cup-shaped cavity formed in it by the point of the tooth which was immediately succeeding it.

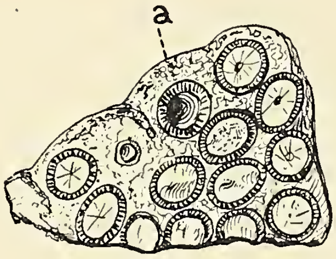

FIG. 6. Showing at *a* that the successional tooth has invaded the cavity of this tooth.

The Palatal Region of the Skull.—Little has hitherto been known of the palatal region of the crania of the sauropods. A reference to the figure of this region of the skull of Diplodocus given by Professor Marsh (See "*Dinosaurs of North America*," Sixteenth Annual Report of the United States Geological Survey, 1894–95, p. 177, fig. 27) which is herewith reproduced, (Fig. 7) shows how very shrewdly Professor Marsh with the more or less crushed and broken material, which he employed, and which is still preserved at the United States National Museum, succeeded in a general way in interpreting the osteology of this portion of the skull. The late Dr. Theodore N. Gill informed me a number of years ago, when I was preparing my paper, "The Osteology of Diplodocus" (Memoirs Carnegie Museum Vol. II, pp. 225–278), that Professor Marsh in order to facilitate

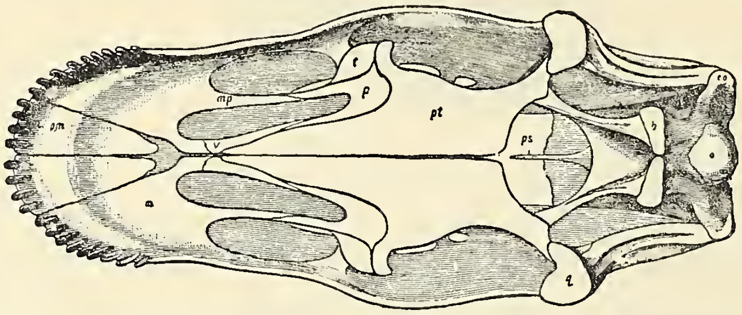

FIG. 7. Reproduction of palatal view of skull given by Professor Marsh. Sixteenth Ann. Rep. U. S. Geol. Surv. p. 177. (Fig. 27.)

examination had separated, so far as it was possible to do so, the component elements of the skulls in the United States National Museum (U. S. N. M. Nos. 2672 and 2673). These specimens when returned to the Geological Survey by Professor Marsh were more or less composed of the disassociated portions, which were subsequently reassembled at the Museum and mounted, as they may now be seen, and as they were at the time when I wrote my paper.

In their present condition it is difficult to obtain satisfactory views of the palatal region of these skulls. The outline given by Professor Marsh approximately agrees in many respects with what is shown in plates XLI and XLII of the present article. There are, however, a number of features in the skull, which we are considering, which reveal points which are not brought out in Professor Marsh's somewhat diagrammatic drawing of this aspect of the skull. ("Dinosaurs of North America," Sixteenth Annual Report U. S. G. S., 1894–95, p. 177, Fig. 27), (See Fig. 7). To these points I desire in the following paragraphs to briefly call attention.

The specimen (Carnegie Museum No. 11,161) is, so far as the writer is aware, the only specimen in existence, which gives an approximately clear view of the entire palatal region of the skull of Diplodocus. The matrix in which this skull was imbedded, as has already been stated, was very soft sandstone. In the interior of the skull the sand which had filled it was very loosely compacted, so that it was possible without much risk to gently remove it without fracturing the very thin and delicate bones, which form the inner walls and supports of the facial region of the skull. However, in the anterior portion, in the region of the paired vomerine bones and the palatines there has been some crushing and there is difficulty in clearly making out some of the sutures.

The Pterygoid and Palatine Bones.—Professor Marsh in his description of this region says: "The palate is very high and roof-like, and composed chiefly of the pterygoids, as shown above in Fig. 27. The basipterygoid processes are elongate, much more so than in the other genera of Sauropoda."

"The pterygoids have a shallow cavity for the reception of these processes, but no distinct impression for a columella. Immediately in front of this cavity the pterygoids begin to expand, and soon form a broad, flat plate, which stands nearly vertical. Its upper border is thin, nearly straight, and extends far forward. The anterior end is acute and unites along its inferior border with the vomer. A little in front of the middle a process extends downward and outward, for union with the transverse bone. In front of this process, uniting with it and with the transverse bone, is the palatine."

The foregoing description by Professor Marsh in many respects is not open to criticism. In Fig. 8 I give a cross-section through the skull made on a plane inclining from the anterior extremity of the quadrate bone through the anterior border of the narial opening, which confirms the statement of Marsh that the palate is "high and roof-like and composed chiefly of the pterygoids." This is absolutely true of the posterior portion of the palatal region. His description of the basipterygoid processes is not open to any criticism. It is, however, I think open to question whether the pterygoid extends as far forward as is represented in his figure. He says "The anterior end" [of the pterygoid] "is acute and unites along its inferior border with the vomer." After a very critical examination of the specimen before me I am inclined to think that the acute anterior projection of the palatal complex, which unites according to Marsh with the vomer, may belong to the palatine. It is difficult, owing to the condition of the skull (Carnegie Museum No. 11,161), to trace the sutures with exactness, but there is a strong suggestion in what is visible that the palatine bone possessed a greater extent than is attributed to it by Professor Marsh. He says of the palatine: "The palatine is a small semi-oval bone fitting into the concave anterior border of the pterygoid, and sending forward a slender process for union with the small palatine process of the maxillary."

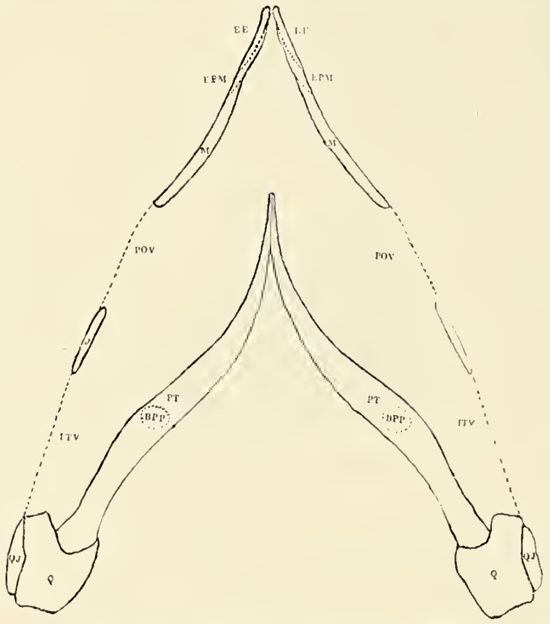

Fig. 8. Section through skull extending from quadrate bone at anterior extremity through the anterior border of the narial opening. BPP, Point where basipterygoid processes unite with back of pterygoids; EE thin plates of bone (prenarials) overlapping the posterior ends of the inner extensions of the premaxillaries; EPM, inner extensions of the premaxillary bones; ITV, infratemporal vacuity; J, jugal; M, maxillary; POV, preorbital vacuity; PT, pterygoid; Q, quadrate; QJ, quadratojugal.

In Fig. 9 at *pl.* is shown the infero-proximal end of the palatal bone, as it appears in the specimen before us, and at *pl. p.* the process of the same, which unites with *p. p. m.*, the palatal process of the maxillary. According to Marsh the union of the palatal bone with the pterygoid should take place on the dotted line marked in this figure *x-y*. But I have a strong suspicion that the palatine entered more largely into the composition of the anterior part of the roof of the mouth, and that instead of terminating along the line *x-y*, it extended inwardly as well as anteriorly to a much larger extent than is indicated by Marsh and formed the thin acutely projecting portions of the roof of the mouth, which Marsh apparently interpreted as anterior projections of the pterygoids. In the specimen of the skull which we are studying there is much to suggest that the palatine coösifies with the pterygoid at the line marked in Figs. 9 and 10 as x-z, and that

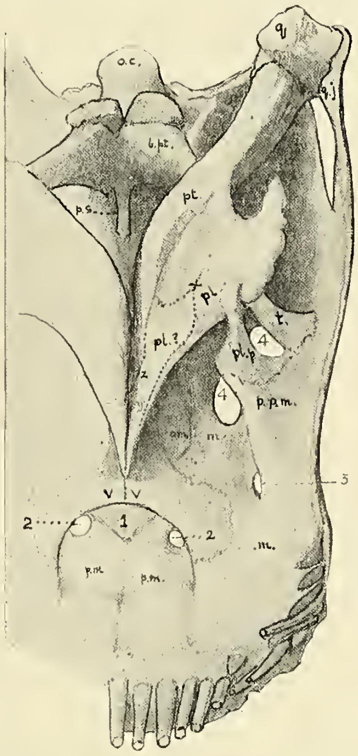

Fig. 9. View from in front looking into the skull of *Diplodocus* (C. M. No. 11,161) along the axial line of the skull, which has been turned upside down, so as to show its inferior aspect. (Lead-pencil sketch by W. J. Holland). *b.pt.*, basipterygoid process; *m.* maxillary; *o. c.* occipital condyle; *pl.*, palatine bone; *pl.*?, inward extension of palatine, not shown by O. C. Marsh, but surmised by author to exist; *pl. p.*, palatine process for union with *p. p. m.*, palatine process of maxillary; *p. m.* premaxillary; *p. s.*, parasphenoid; *pt.*, pterygoid; *q.*, anterior end of quadrate; *q. j.*, quadratojugal; *t.*, transverse bone; *v. v.*, prevomer; 1. matrix lying between vomerine arch and premaxillaries; 2. anterior foramina between maxillaries and premaxillaries; 3. posterior end of large mesial foramen (*Cf* Mem. C. M., Vol. II, p. 240); 4. preorbital vacuity.

it may even have extended still further backward, as far as the line marked in Fig. 10 as x-z′. I am not prepared to absolutely negative the correctness of Professor Marsh's figure and scanty description, nevertheless, after a careful examination of the material before me, I am strongly inclined to think that Professor Marsh erred in restricting the boundaries of the palatine bone, as he has done.

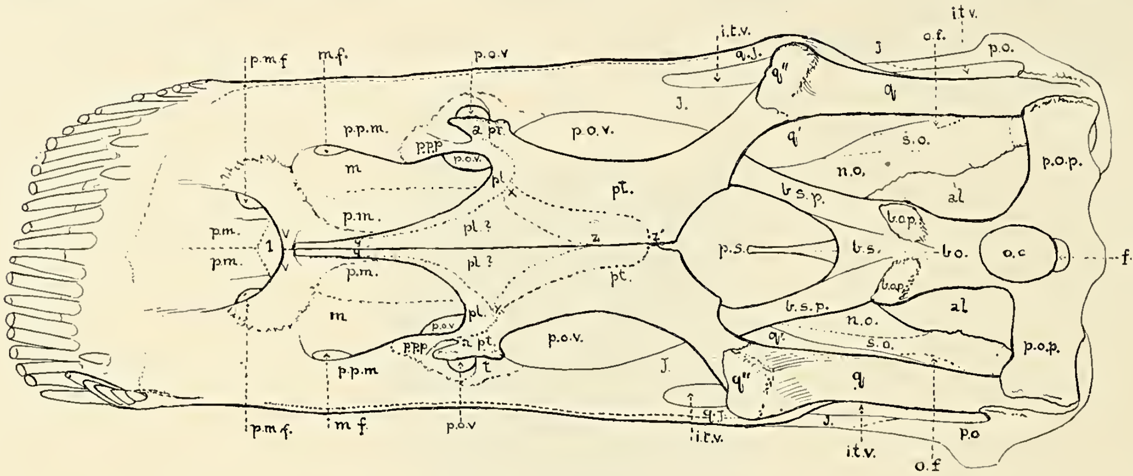

Fig. 10. Outline of basal view of skull of Diplodocus. *al.*, alisphenoid; *a. pt.*, anterior lower end of pterygoid; *b. o.*, basioccipital; *b. o. p.*, basioccipital process; *b. s.*, basisphenoid; *b. s. p.*, basipterygoid process; *f. m.*, foramen magnum; *i. t. v.*, infratemporal vacuity; *j.*, jugal; *m.*, maxillary; *m. f.*, mesial foramen of maxillary; *n. o.*, narial opening; *o. c.*, occipital condyle; *o. f.*, orbital vacuity; *pl.* and *pl?*, palatine; *p. m.*, premaxillary; *p. m. f.*, premaxillar foramina; *p. o. v.*, preorbital vacuity; *p. o. p.*, paroccipital process; *p. p. m.*, palatal plate of maxillary; *p. p. p.*, anterior lateral process of palatine coössifying with *p. p. m.; p. s.* parasphenoid; *q.*, quadrate; *q′.*, ascending flat inner platelike extension of quadrate; *q″*, anterior articular surface of quadrate; *qj.*, quadratojugal; *s. o.*, supraorbital; *t.*, transverse; *v. v.*, prevomer; *x-y*, inner boundary of palatine as suggested by Professor Marsh; *x-z*, inner boundary of palatine as suggested by the author; with *x-z′*, possible further inner extension of posterior boundary of palatine suggested by the author. 1. vacuity filled with matrix interposed between prevomer and premaxillaries.

There appears, as I write, to be in the specimen before me (Carnegie Museum No. 11,161) much to suggest the view just expressed and that the palatine is found to correspond more nearly in its extent and outline with what we know of this element in many other reptiles.

The Vomer.—Professor Marsh says: "The vomer is a slender triangular bone, united in front by its base to a stout process of the maxillary, which underlaps the ascending process of the premaxillary. Along its upper and inner border it unites with the pterygoid, except at the end, where for a short distance it joins a slender process from the palatine. Its lower border is wholly free."

In the specimen before us the bone which Marsh designates as the vomer is clearly revealed, but its position and outline is somewhat different from that given by Professor Marsh in his figure ("*Dinosaurs of North America,*" Fig. 27)

(See Fig. 7 of this paper) to which we have been referring. The vomer consists of two paired bones which form the postero-inferior boundaries of an arch which underlies an opening at this point between the re-entering portions of the maxillaries, which, as Marsh says, "underlap the ascending processes of the premaxillaries." In the specimen before me this opening has a depth at the middle of at least fifteen millimeters, by which space the premaxillaries at the middle line are separated from the maxillaries. Professor Marsh's statement that the vomer "along its upper and inner border unites with the pterygoid, except at the end where for a short distance it joins a slender process from the palatine", which in the previous paragraph he had described as "a small semi-oval bone sending forward a slender process for union with the small palatine process of the maxillary," seems to plainly reveal a defect in his description of the palatine, and accords with what I have already stated to be my surmise as to the form of the palatine bone. If my interpretation of the structure of the palatine is correct, and in a general way I think it is, the paired vomers (prevomerine bones) unite posteriorly with the palatine (not with the pterygoids, as Marsh says). Figs. 9 and 10 and Plate XLI, Fig. 2, show the location and contour of these paired prevomerine bones as they appear in the specimen which we are studying. At their outer extremities they are broadly expanded and flattened plates, which are adnate upon the lower surfaces of the maxillaries. These plates are in part what Marsh interpreted as "a stout process of the maxillary." The "stout process of the maxillary" of Marsh is in fact largely composed of the widened and flattened ends of the prevomerine bones. Concerning this element of the skull it is well to consult R. Broom "*On the Structure and Affinities of Udenodon*," P. Z. S., 1901, II, p. 184, where this careful observer points out that in the reptiles generally the *parasphenoid* should be called the vomer, and functions as such, "while the anterior paired element, usually regarded as the 'vomer,' but which is the homologue of the dumbbell-shaped bone in *Ornithorhynchus*, may be called the 'anterior vomer' or by the name I have elsewhere[7] proposed for convenience, the 'prevomer.' "

The Posterior Region of the Skull.—In my paper upon "The Osteology of Diplodocus" (Mem. Carn. Mus., II, 1906, pp. 225–278) I undertook with such light as I then possessed, to give a detailed account of the fragment of a skull (Carnegie Museum No. 662 (22)) upon which we had in part founded the restoration of the posterior part of the skull of Diplodocus, used in preparing replicas of the animal for presentation to various foreign museums. I had examined this fragment very carefully and had discussed its features with Dr. O. P. Hay and a number of other eminent students of reptilian anatomy both at home and abroad, and they all had in the main agreed with the correctness of my interpretation of the various component elements, so far as these are capable of being determined without breaking up the specimen.

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[7] Broom, R. "On the Homology of the Palatine Process of the Mammalian Premaxillary," Proc. Linn. Soc. of New South Wales, X, 1895, p. 484.

After my paper had appeared, Dr. O. P. Hay through the United States National Museum requested and obtained permission to re-examine the fragment, and subsequently published in Science, N. S., Vol. XXVIII, p. 517, a communication, in which he announced his dissent in some particulars from my interpretation of the osteology of this fragment. To his critique I in part replied in the same volume of Science, at p. 644. In my reply I admitted that very possibly I had fallen into some errors and stated, that, when the time for a leisurely and careful re-examination of the subject might arise, I would again revert to the subject, so far as it relates to the interpretation of the bones forming the cerebral walls of the skull. The opportunity for such a revision has at last come, and with the material before me I am in position in part to confirm the correctness of some of Professor Hay's criticisms, though there are others in which I am not as yet able to concur with him.

Before proceeding further I wish at this point to renew attention to the fact, to which I have already incidentally alluded in the present paper, that the fragment which I carefully figured in my Memoir (*l. c.* Figs. 4–10) reveals some well-defined differences from the basal portion of the skull (Carnegie Museum No. 11,161, as well as all other skulls of Diplodocus recently re-examined by me. One of the most noticeable differences is the fact that the anterior projection of the bone which I called the "presphenoid" (Dr. Hay says I should have called it the *parasphenoid*) lies on the same plane as the basisphenoid, and might be interpreted as a very short anterior prolongation of the latter. In the skull, Carnegie Museum No. 11,161, the parasphenoid originates at a point about 30 mm. higher up than the projection in the skull of C. M. 662 (22) and is a long, slender bone directed forward and upward into the narial cavity on a quite different plane from the bone illustrated in the figures of the fragment given in my paper to which reference has been made. This bone thus corresponds far more closely to what we know of the parasphenoid from the figure given by Professor Marsh in his cut (*Dinosaurs of North America*, p. 177, Fig. 27). In the text Marsh does not mention the parasphenoid. In the specimen No. 662 (22) this bone is lost. In the specimen No. 662 (22) the lower surface of the exoccipital processes is very deeply excavated, or hollowed out anterio-posteriorly, which is not the case in the specimen No. 11,161, where these surfaces are antero-posteriorly convex. This difference I regard as being at least specific. There is also to be pointed out the fact that in the fragment No. 662 (22) there is no fontanel on the upper surface of the skull in the parietal region, as is also the case in our skull, No. 3,452, while in skull No. 11,161 such a fontanel is quite apparent, as also in Carnegie Museum No. 11,162, in the specimens in the National Collection, and as is shown in the case of the restoration of the specimen in the American Museum of Natural History (No. 969). Having based our restoration of the posterior part of the skull upon Specimen No. 662 (22) we have shown no fontanel at this point, but on Plate XLI of the present paper this opening is clearly shown as it exists in Carnegie Museum No. 11,161. Whether the presence or absence of such a fontanel is due to age, or not, may be open to question. It is positively lacking in specimen No. 662 (22) and 3,452. This combination of differences leads me to think that this specimen, (662 (22)), though otherwise thoroughly diplodocine in character, may well represent a species of the genus different from that with which we are mainly dealing in this paper, (Carnegie Museum No. 11,161), which specimen I refer provisionally to *Diplodocus longus* Marsh.

In honor of Professor O. P. Hay I venture to call the specimen Carnegie Museum 662 (22) *Diplodocus hayi* (holotype) trusting that the learned Doctor will not take exception to this act of mine. It may be distinguished from the other species of the genus by the points to which I have called attention in the preceding paragraph, and it is well figured in my paper on the "*Osteology of Diplodocus*" Memoirs Carnegie Museum, Vol. II, text-figures 4–10, Fig. 4, having been reproduced in Abel's "*Die Stämme der Wirbeltiere*," page 609, figure 477.

The Superoccipital.—Dr. Hay takes exception to my interpretation of the superoccipitals while at the same time stating that my interpretation of the exoccipitals is correct. He states in regard to the superoccipital, "in all reptiles this bone, by virtue of its epiotic element, takes an essential part in the formation of the internal ear, containing, as it does, the posterior semicircular canal. It must, therefore, come into contact with the exoccipital and the proötic not far above the fenestra ovalis. The three bones concerned are, in the Pittsburgh specimen and all others known, thoroughly coössified and the sutures are nearly effaced. However, the writer believes that the suture between the supraoccipital and exoccipital starts about 25 mm. above the fenestra ovalis and runs outward and backward to a notch in the hinder border of the post-temporal fossa. In Dr. Holland's figure 5 this suture would start from the suture ascending at the left of the letters *ex. o.*, at the upper border of the postfrontal bone and run backward just below these letters, and end under the bone *sq.*" The point made by Dr. Hay, as here quoted, is well taken by the writer after a thorough re-examination of specimen 662 (22) and more especially after a critical examination of the same region of the skull in specimen No. 11,161. The presence of the posterior portion of the superoccipital where it is shown on a rear view of the skull, (Memoirs Carnegie Museum, Vol. II, p. 235, Fig. 6), is approved by Dr. Hay in his article and is confirmed by specimen No. 11,161. I failed to recognize the lateral extension of this bone running under the squamosal and reappearing at its lateral extremities to form a portion of the inner wall of the supratemporal fossæ. Dr. Hay was not positive in his statement of the external limitations of this bone at this point, but, so far as the new specimen No. 11,161 is concerned, it seems that there is confirmation of his view, especially when the supratemporal fossa of the left side of No. 11,161, is critically examined. The suture between the superoccipital and exoccipital is rather distinctly shown in this specimen, but lies somewhat further down than on the line suggested by Dr. Hay, coössifying with the exoccipital below the middle of the supratemporal fossa, where also the hind margin of the proötic is clearly seen overlapping the inner surface of the exoccipital at this point. Where these bones, the superoccipital, the proötic, and the exoccipital, converge in our specimen No. 11,161 is found, I think, the fenestra ovalis near the base of the supratemporal fossa.

As to my interpretation of some of the smaller foramina, to which Dr. Hay takes exception, I may say that our specimen, No. 11,161, does not reveal as clearly as the fragment No. 662 (22), a number of the smaller foramina, which I endeavored to interpret, and I am therefore not ready for the present either to accept or reject Dr. Hay's suggestions, I am not prepared to unhesitatingly coincide with Dr. Hay's suggestion that the trilobate foramen which appears near the commissure of the proötic and the alisphenoid (it is only partially shown in my Fig. 5, Memoirs Carnegie Museum, Vol. II, p. 233, being in part concealed by the downward projection of the postorbital bone) might be interpreted as the fenestra ovalis in specimen No. 662 (22). According to Dr. Hay, if I understand him correctly, this opening in his opinion might have served both as the exitus for the facial nerve (trigeminal opening) and as the fenestra ovalis. I called it the trigeminal foramen. The opening, which I designated as the fenestra ovalis, which is near the above-mentioned trilobate opening, Dr. Hay dubiously asserts may have been the exitus of the ninth pair of nerves, and that the tenth pair escaped through the foramen which I designated with the numerals IX. Unfortunately the specimen No. 11,161, does not allow of the exploration of the foramina at these points. However, by peering through the opening of the orbit the outer walls of the cranium are partially visible in this specimen and in Fig. 11 I give a somewhat diagrammatic outline of the bones, as they appear in the skull, together with the foramina which on this view are visible. In our specimen No. 11,161, at the point where the proötic coössifies with the downward and outward extension of the superoccipital and the exoccipital, as I have already observed, there appears to be a foramen (concealed in Fig. 11) which in my judgment is the fenestra ovalis. In specimen 662 (22) there is apparently a very small opening corresponding in location with the fenestra ovalis in specimen No. 11,161. The trigeminal foramen is where I placed it in my figure 5, and where it also appears to be in the specimen No. 11,161.

The Parietals.—It is worthy of record that the parietal bones in specimen No. 11,161 near the median line of the skull are shown to have a somewhat more forward extension than is shown in the figures I gave of the fragment No. 662 (22). They form in part the lateral boundaries of the vacuity shown at this point in skull No. 11,161.

Orbitosphenoid.—In Fig. 11 at *o. sph.* is shown the orbitosphenoid which in specimen No. 11,161 is very well preserved and to a considerable extent forms the rear wall of the orbital cavity. It was no doubt more or less cartilaginous in

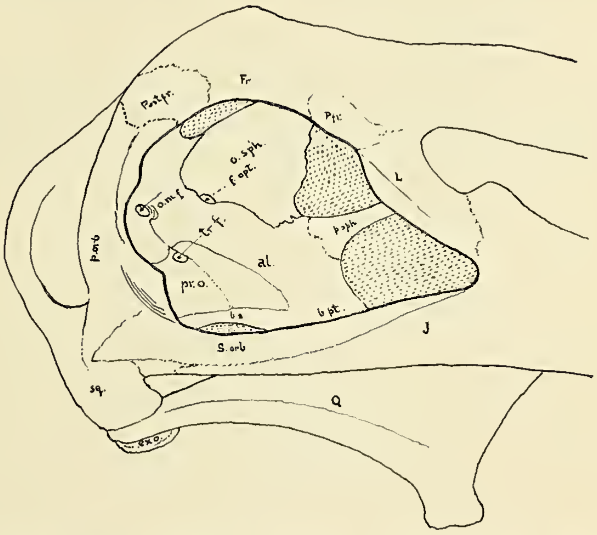


FIG. 11. Side view of posterior region of skull of Diplodocus (C. M. No. 11,161) looking into orbital opening, which is defined by heavy line. *al.*, alisphenoid; *b. pt.*, basipterygoid process; *b. s.*, basisphenoid; *exo.*, exoccipital; *f. opt.*, foramen opticum; *Fr.*, frontal; *J.*, jugal; *L.*, lachrymal; *o. m. f.*, oculomotor foramen (?); *pr. o.*, proötic; *o. sph.*, orbitosphenoid; *P. fr.*, prefrontal; *p. orb.*, postorbital; *p. sph.*, parasphenoid; *Q.*, quadrate; *S. orb.*, suborbital; *sq.*, squamosal; *tr. f.*, trigeminal foramen. The dotted areas indicate vacancies or unremoved matrix.

its structure, and is preserved in this specimen in the same way as is the sclerotic membrane of the eye.

The Posterior Articulation of the Quadrate.—Specimen No. 11,161 and specimen No. 3,452 in our collection show very plainly that the proximal end of the quadrate is firmly wedged in between the exoccipital and a thin downward lateral projection of the squamosal. There is here an overlapping by the proximal end of the suborbital. This feature is perhaps best shown in specimen No. 3,452, where a slight disarticulation in this region has taken place, without injury to the bones, so that the lines of union at this point are clearly brought into view.

The Premaxillary Process.—In my paper (Memoirs Carnegie Museum, Vol. II, p. 238), I said: "Ranging backward from the premaxillaries, located between the maxillaries, are the two long slender bones, which Professor Marsh interprets as backward prolongations or processes of the premaxillaries, but which may be regarded as lateral ethmoids. These bones on the median line of the skull unite to form a raised ridge, which is higher in front than behind. At the anterior point of commissure the bones widen outwardly somewhat and terminate in blunt, outwardly obliquely truncated ends, which are raised above the level of the premaxillaries and maxillaries. There are at this point two moderately large foramina, one on either side, the purpose of which is yet to be determined, but which correspond more nearly in location to the nares as ordinarily found in the reptilia than any other openings in the skull."

This paragraph calls for radical modification in the light of the new material. It appears that the long backward projections of the premaxillaries from the openings of the foramina, to which allusion has been made in the foregoing quotation, are overlapped on either side by long narrow bones which on their anterior edges unite about half way between the above mentioned foramina and their posterior extremities on the median line. I spoke of these bones as the "lateral ethmoids" following the analogies of the skull of fishes. Perhaps it would be better to call these long slender bones prenarials. Their location is shown on Plate XLI, Fig. 1. They are visible in our specimen No. 11,161, also appear in the large skull No. 11,162, and are quite distinctly visible in our specimen No. 11,255. (See Plate XLIII).

It is worthy of remark that the skull of Diplodocus in many respects suggests ornithic features and that it is widely different in many respects from the skulls of the Crocodilia, the Testudinata, and the Lacertilia, with all of which comparison has been made.

SKULL (No. 3452) ARTICULATED WITH THE CERVICALS.

A figure of this skull and the cervicals associated with it is given on Plate XL, Fig. 2. The specimen is highly interesting because of the immediate association of the skull with the cervicals. It establishes beyond a doubt that no mistake has been made in associating with the vertebræ which belong to Diplodocus the skull hitherto consistently attributed to that genus. In this specimen the occipital condyle of the skull lies almost within the cup of the atlas, and the seven following cervicals are found lying near by as they are represented on the plate.

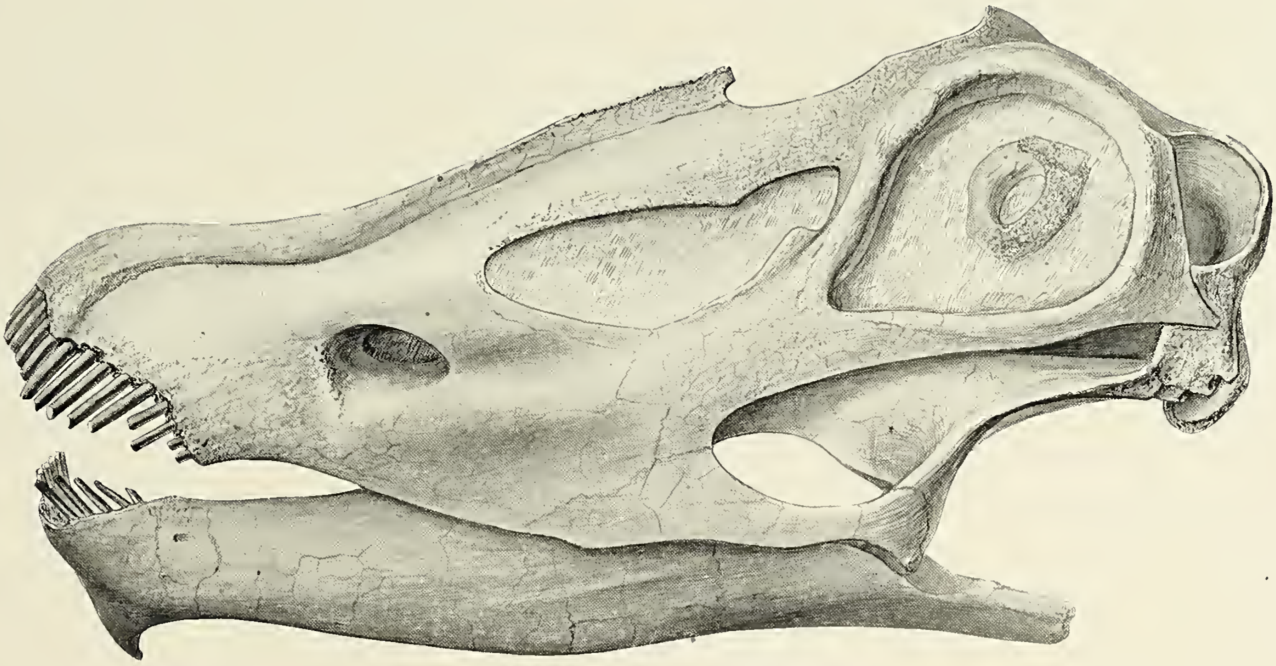
SKULL (No. 11,255).

A view of the right side of this skull is given on Plate XLIII. It is, so far as the writer is aware, the smallest skull representing the genus, which has thus far been discovered. It has been strongly crushed laterally, and much of the occipital region, including a small portion of the occipital condyle, is missing.

The length of the skull from the rear of the occipital condyle to the anterior margin of the infra-maxillaries is only 290 mm. While in part defective, this skull agrees in most respects with the others we have studied, but differs noticeably, as has been already observed, in having all the teeth sharply pointed, and showing no traces of transverse wear. The sutures are fairly well defined, and show nothing essentially different from what has been observed in the other skulls which have been studied. The prenarials are plainly revealed as separate elements.

Great credit should be given to Mr. L. S. Coggeshall and Mr. S. Agostini for the extremely skilful manner in which they succeeded in freeing from the matrix the skulls belonging to the Carnegie Museum which are mentioned in the foregoing pages.

Carnegie Museum
Sept. 1, 1921.



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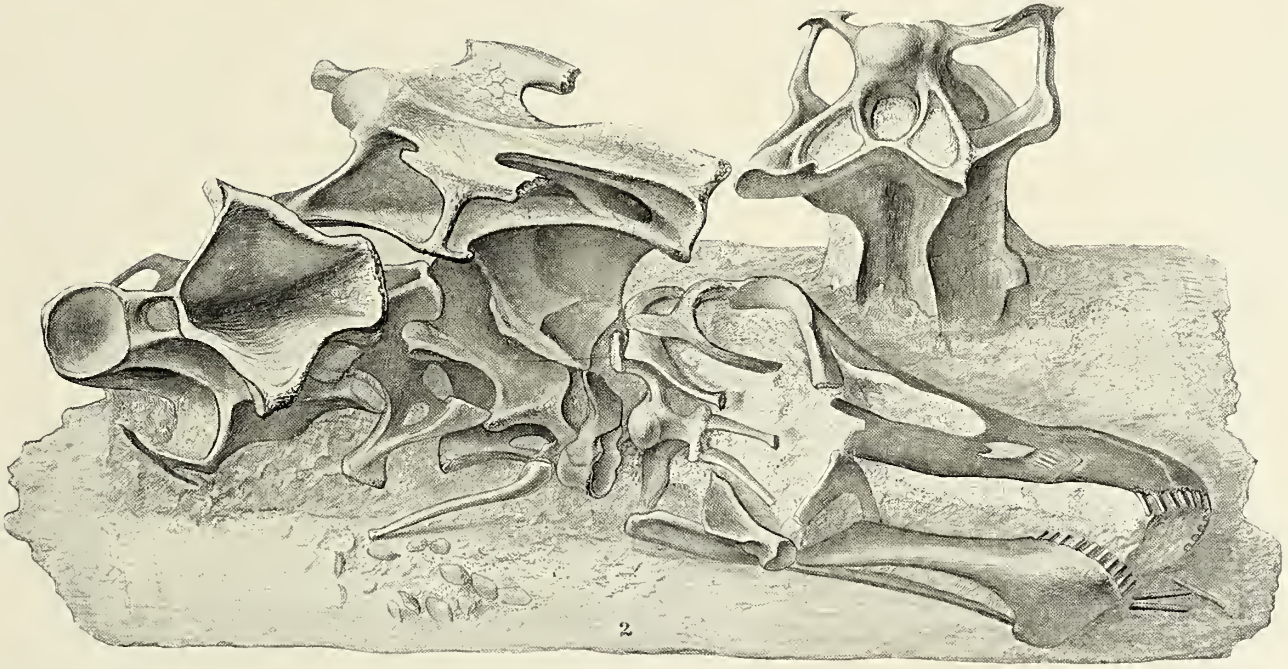

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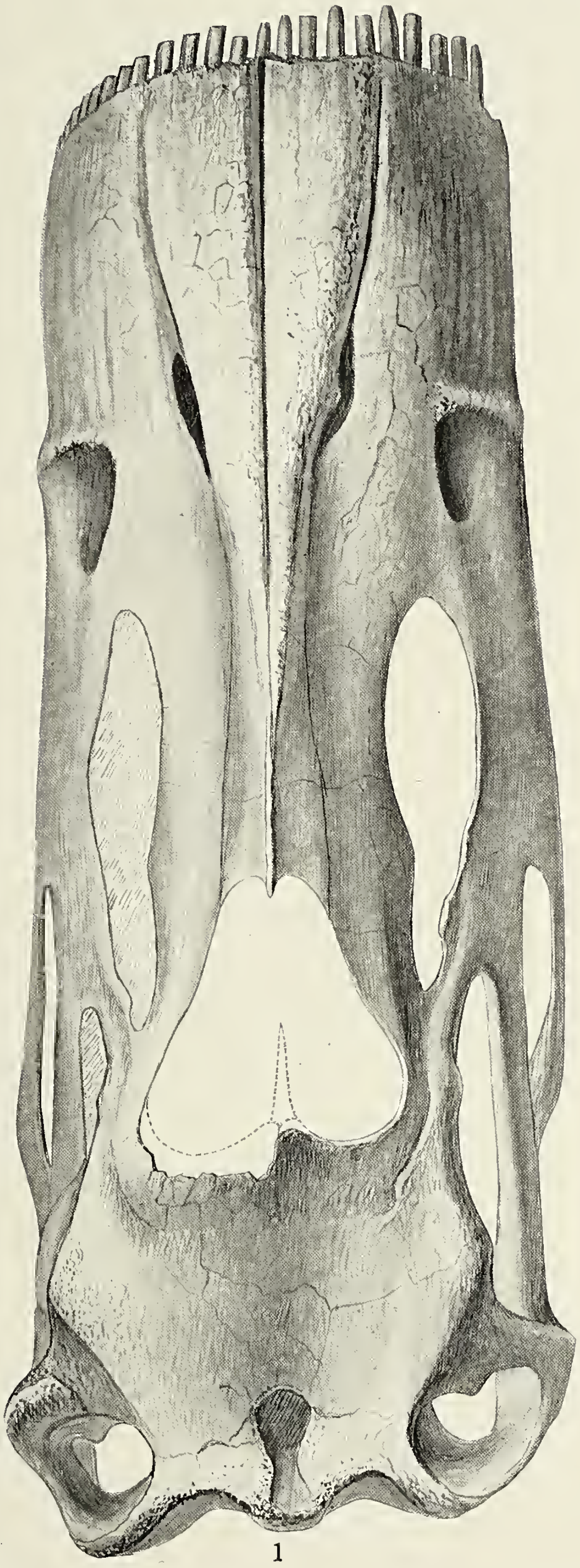
Fig. 1. View of left side of skull of Diplodocus, C. M. No. 11,161, showing remnants of eye-ball in place. Three-tenths nat. size.

Fig. 2. Skull and cervical vertebræ of Diplodocus, C. M. No. 3452. One-fifth nat. size.

(From wash-drawings made by Sydney Prentice)



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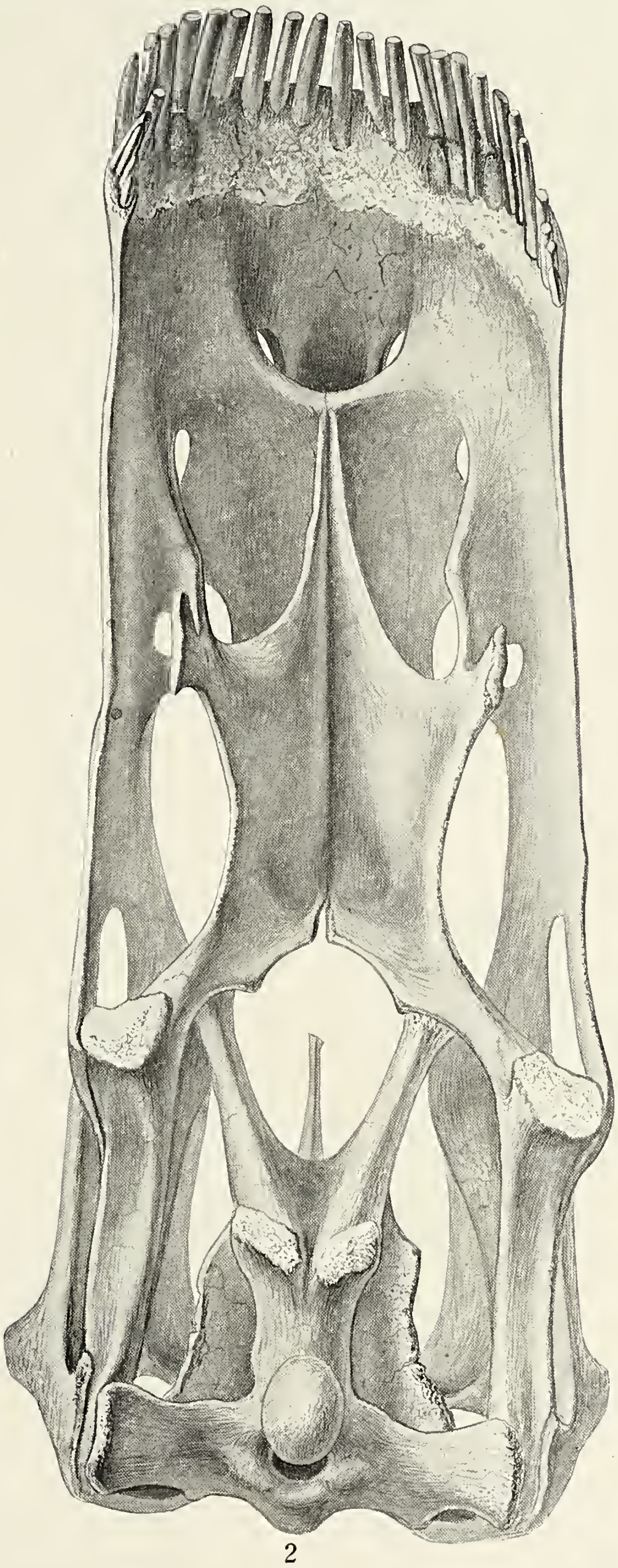

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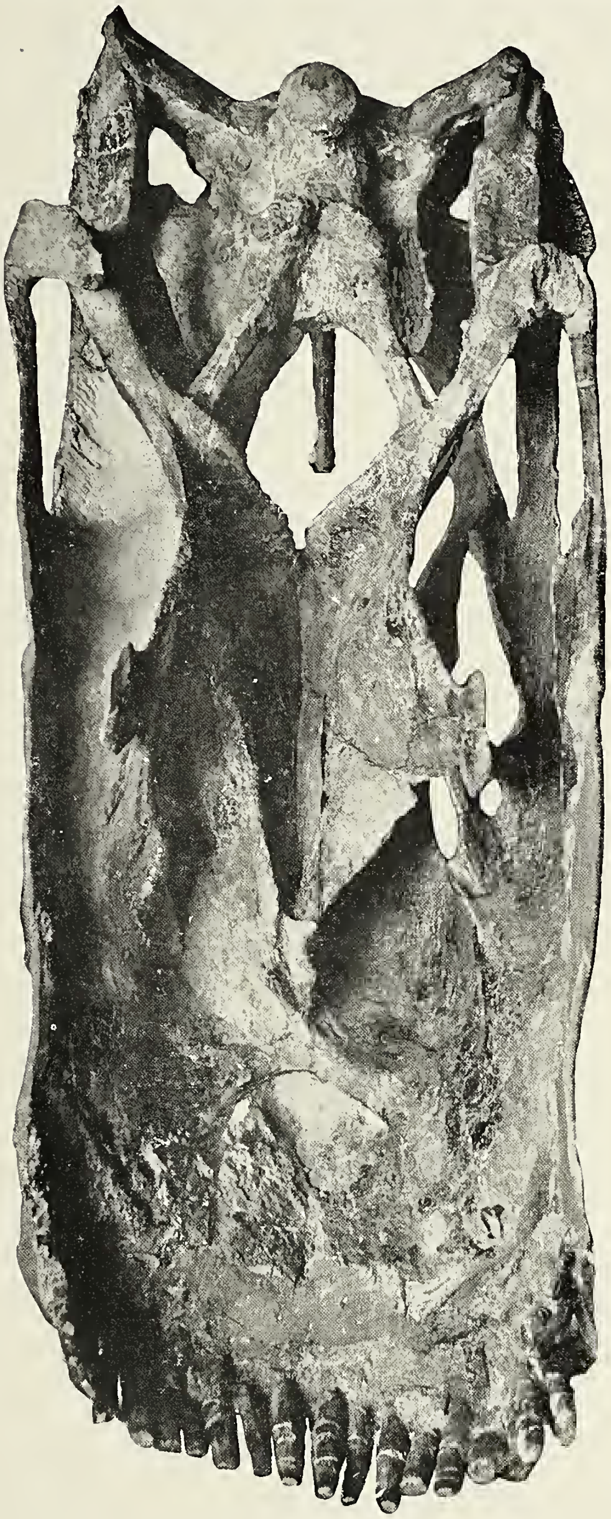
Fig. 1. Superior view of outer surface of skull of Diplodocus, C. M. No. 11,161. Two-fifths nat. size.
Fig. 2. Palatal view of skull of Diplodocus, C. M. No. 11,161. Two-fifths nat. size.

(From wash-drawings made by Sydney Prentice)



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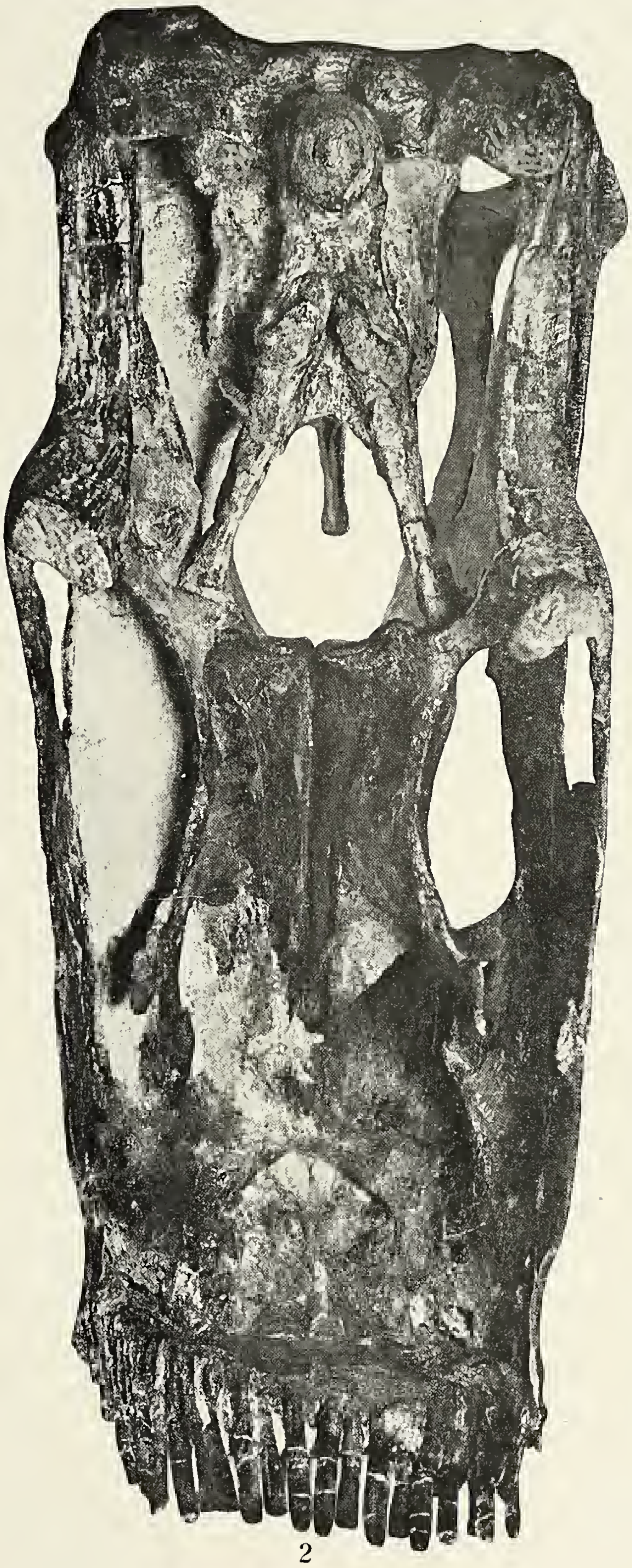

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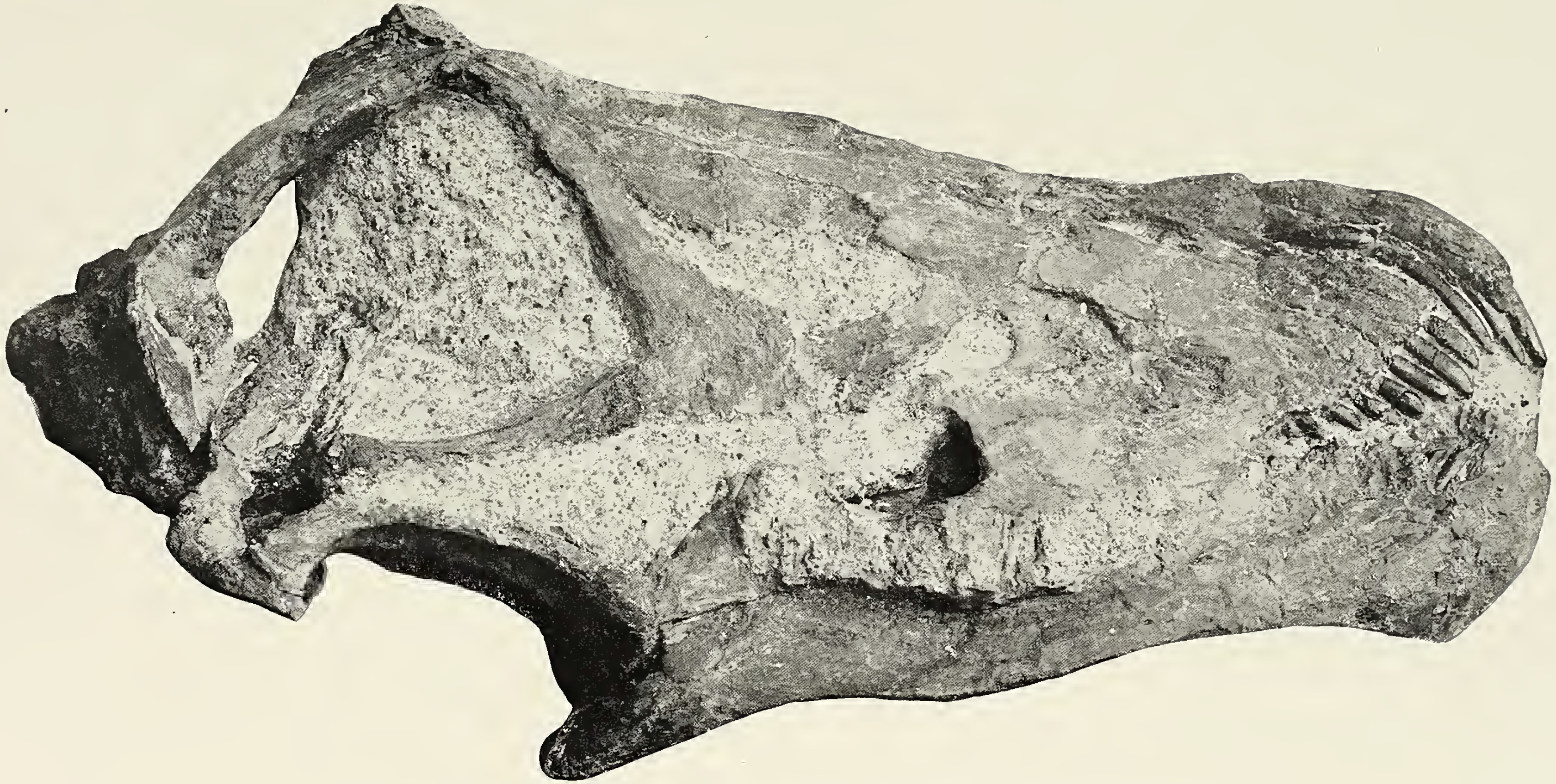
Fig. 1. Photograph of palatal view of skull of Diplodocus, C. M. No. 11,161, about one-third nat. size. The view is taken looking down into the skull at an angle of about 45° with the axis. Illumination from the left.

Fig. 2. Photograph of palatal view of skull of Diplodocus, C. M. No. 11,161, about one-third nat. size. The view is taken directly from above perpendicularly to axis of skull. Illumination from the right hand side.



Skull of Diplodocus. C. M. Cat. Vert. Fossils, No. 11,255. Three-fifths nat. size.